Superconductivity Program

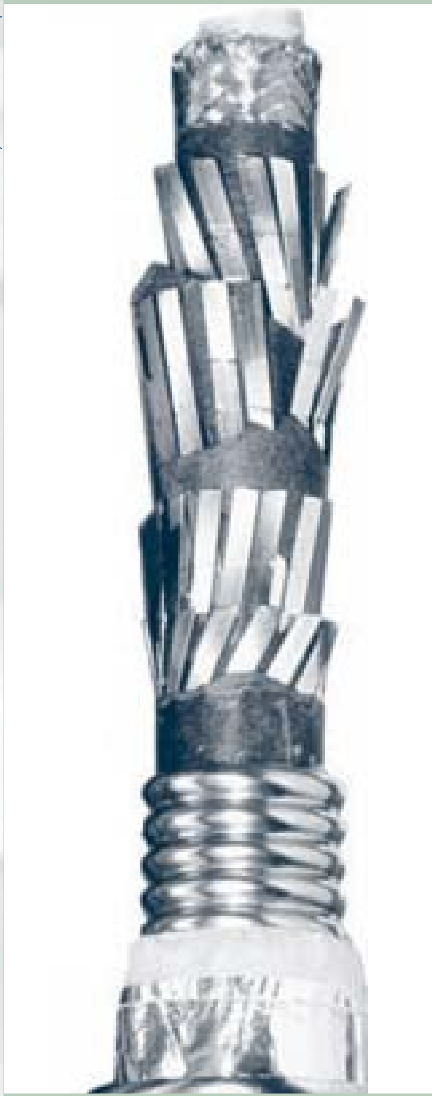
Technology Overview

In the next five years, high-temperature superconductivity (HTS) could bring a more fundamental change to the electric power industry than has occurred in the last 100 years. Superconductivity can provide a super-power conductor that greatly improves efficiency and power capacity over conventional copper or aluminum wires, can help provide relief to an overloaded electrical transmission system, and can help avoid major outages.

Resistance is a measure of the opposition of atoms to the flow of electricity, and the electrical energy lost due to resistance is converted to heat. Superconductivity is the property of certain materials to conduct electricity without resistance when they are cooled to extremely low temperatures. In 1986, a new group of ceramic materials was discovered which become superconducting at temperatures in the range of minus 320 degrees to minus 280 degrees Fahrenheit (a temperature range that can be achieved with liquid nitrogen). These new materials were named high-temperature superconductors to distinguish them from the low temperature metallic materials (discovered in 1911) that are superconductors below minus 440 degrees Fahrenheit.

Crystalline oxide material of high-temperature superconductors is brittle and is not well suited to making wire by traditional methods. Through several years of research, the technology has developed to bond the crystalline oxide superconductor materials to metals that provide some of the flexibility required for wires. Superconducting wires now being developed are expected to have 100 times the power capacity of conventional wires. This increased capacity makes possible electric power equipment that will be half the size of similarly powered conventional alternatives and will have half the energy losses. Superconducting electrical-system equipment such as generators, transformers, fault-current limiters, flywheels, transmission cables, and motors will have increased performance benefits, including reduced environmental impact, longer operating life, greater safety, and higher overload thresholds.

Photo courtesy of Pirelli Cable Corp.



Cut-away view of an HTS cable. The central tube at the top carries the liquid nitrogen coolant, and the four layers of superconducting tapes in the upper part of the picture conduct the electrical current. Insulation and shielding make up the outer layers of the cable.

U.S. Department of Energy Program

The High-Temperature Superconductivity Program of the U.S. Department of Energy is working in partnership with industry to solve the difficult challenge of manufacturing electrical wire from the ceramic HTS materials.

Industry participants are asked to consider new approaches to bring HTS technology to the marketplace. These public-private partnerships are creating designs and testing pre-commercial prototypes of super-efficient power devices that use these wires. At the same time, the HTS Program is working with national laboratories and universities to conduct research to understand the basic principles of superconductivity.

At present, most superconducting wire is manufactured by some variation on the powder-in-tube (PIT) method. In this method, silver tubes are packed with superconducting powder followed by processing steps that squeeze and heat the tubes to produce long lengths of flexible wires. Kilometer lengths are now routinely made and are available from manufacturers in the United States, Europe, and Japan. The PIT wire is improving rapidly and has been used in the production of all pre-commercial prototypes of superconducting equipment developed and tested by DOE-industry partnerships. However, the PIT process also causes imperfections in the structure of the superconductor, and this limits current-carrying ability to a level well below potential. The economic and energy impacts are predicted to be huge, but many challenges must still be addressed in order for superconductivity to play an important role in modernizing the U.S. electric power system.

HTS Motors Show Promise for Industry

Since industrial electric motors consume most of the electricity used in a typical manufacturing operation, increased efficiency should yield significant savings in power costs. Rockwell Automation has led an industry team in partnership with DOE that successfully demonstrated and tested a 1,000-horsepower HTS motor. The motor uses cryogenically cooled HTS wires in its rotating coils. Motors using these HTS rotor coils are expected to be half the weight and size of conventional motors and would provide greater operating efficiency.

Photo courtesy of American Superconductor

Motors using HTS coils will be half the size and weight of conventional motors and will operate at higher efficiencies. These coils were used in the 1,000-horsepower HTS motor.

MARKET POTENTIAL

Deregulation and restructuring of the electric power industry is causing large-scale changes in electricity transmission patterns, and the national electric grid will need much greater flexibly and reliably as more states open their markets to competition. Meeting these new demands requires significant upgrading to the existing electricity infrastructure.

Upgrading will also be needed to accommodate expected load growth as well as to replace existing equipment, most of which will exceed its design lifetime during the next 15 years. Commercial versions of the superconducting power equipment now under development will become available during the next 3 to 10 years, matching the large window of opportunity presented by the need for more efficient, higher capacity, reliable equipment. Meanwhile, the research and development projects described below are being conducted to address the technical and economic barriers to commercial introduction of HTS power equipment.

One of the first commercial markets for HTS equipment will be the replacement of aging underground cables that have become bottlenecks in limiting electricity supply and economic development in urban areas. The very disruptive and extremely expensive process of excavating to install new power lines can be avoided by replacing existing cables with HTS cables that carry three to five times more electricity than contemporary copper cables. An industry consortium led by Pirelli Cables is working in partnership with the U.S. Department of Energy on a cost-shared project to manufacture, install, and test a complete HTS power-cable system in the Frisbie substation of Detroit Edison, in downtown Detroit. The cable fits into existing conduit channels and is designed to transmit 100 megawatts of power, serving approximately 14,000 customers. The conductor for each of three phases is fabricated in a single 420-meter length and is designed to carry an alternating current of 2400 amps with superconductor electrical losses of less than 1 watt-per-meter per phase.

Superconducting transformers eliminate the risks of fire and hazardous spills associated with the dielectric oil that surrounds the copper coils in today's power transformers by using environmentally safe liquid nitrogen to cool the superconducting coils. Waukesha Electric Systems and its industry partners worked with DOE to complete design and construction of a 10-megawatt pre-commercial prototype transformer that will be tested at the Waukesha Electric plant in Wisconsin.

Since industrial electric motors consume most of the electricity used in a typical manufacturing operation, increased efficiency should yield significant savings in power costs. Rockwell Automation is leading the industry team in partnership with DOE in demonstrating and testing the 1,000-horsepower HTS, continuous duty, motor system. This motor has a cryogenic superconducting rotor with a brushless exciter. Motors utilizing these superconducting rotor coils are expected to be half the weight and size of conventional motors and would provide greater operating efficiency. The design, prototype construction, and testing of a 5,000-horsepower motor by Rockwell Automation is the next step in the development of large-scale commercial electric motors.

For More Information:

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